Memorandum

US Department of Transportation

Federal Highway Administration

Subject **INFORMATION**: Conformity and Nitrogen Oxides (NOx)

Date MAY 17 1994

From Director, FHWA Office of Environment and Planning
Director, FTA Office of Planning

Reply to Attn of HEP-41

To Directors, FHWA Office of Planning and Program Development (Regions 1-7 and 10)
Directors, FHWA Office of Program Development (Regions 8 and 9)
Directors, FTA Office of Program Development (Regions 1-10)

On March 10, 1994, we provided you with information and guidance on NOx emissions because of the difficulty that some State and metropolitan areas are experiencing with the new NOx requirements in the EPA's transportation conformity regulation. Attached is further information on efforts being made to understand and evaluate the NOx impacts of transportation plans and programs. The material summarizes what we have learned from Ohio's NOx modeling experiences, and suggestions we provided to further refine their NOx modeling capabilities.

Some key observations and conclusions from the Ohio analyses are as follows:

o The TRB Highway Capacity and Quality of Service Committee is currently updating the curves which reflect the speed versus volume/capacity ratio relationships. These new curves show a much flatter speed curve when compared to volume to capacity ratios than those included in the 1985 HCM. This tends to reduce the differences in the modeled NOx emissions between the build and no-build alternatives. It is permissible to use the new speed curves in current conformity analyses.

o On the other hand, the new curves tend to generate higher total NOx emissions estimates for both the build and no-build alternatives because the new curves reflect higher and more consistent speeds even as the volume to capacity ratios increase. This may create some problems in meeting the modeled hydrocarbon emissions budgets, and future NOx emission budgets. This is particularly true if the budgets are established using the speed versus volume/capacity curves in the 1985 HCM and the conformity analyses are completed using the newer curves. If this is the case, the SIP emissions budgets may need to be revised to reflect the new speed curves, since speed is an important factor in MOBILE5A for estimating emissions.

- Speed enforcement on the freeway system can reduce NOx emissions. The Ohio NOx model analysis demonstrated that enforcing the speed limit on freeways between 11 p.m. and 1 a.m. could eliminate the NOx problem in the city of Cincinnati, because of the high percentage of truck traffic during this period. Truck traffic contributes a disproportionate amount of the total mobile source NOx emissions--approximately 40-50 percent of NOx from highway vehicles. Speed enforcement, however, can only be used in the conformity analysis if it is a specific mitigation measure which is directly linked to the build alternative.

- The Ohio DOT estimated their traffic volumes and speeds on an hourly basis for individual links. The link level focus of the emissions calculation is both valid and necessary. Improvements to individual, low speed, congested links can generate NOx reductions because the speeds for the no-build alternative are typically below the minimum point on the "U" shaped NOx curve in MOBILE5A. These emission reductions might not show up with a higher average speed calculated over a widespread area. However, it may not be necessary to calculate speeds and emissions on an hourly basis. Four or five aggregate time periods over the course of the day may suffice (e.g. a.m. peak, off-peak day, p.m. peak, evening off-peak, late night off-peak).

Another potential source of NOx reductions is from traffic flow improvements and demand management on highly congested arterial and local roadways. Typically, under the no-build alternative, these facilities operate at speeds below the NOx minimum point for significant time periods of the day. Any NOx increases from freeway improvements can often be offset by NOx reductions on arterials and local streets. This occurs on facilities parallel to the freeway because of traffic diversions, but this can also be aggressively pursued by including transportation demand management strategies and/or traffic flow improvement projects in the TIP for small congested facilities throughout the region as an offset for any emissions increases for the freeway or other high speed facility.

The best way to estimate emissions reductions from small facility improvements is to incorporate them into the simulation model network. This procedure directly estimates the effect of these improvements on operating speed and VMT. If the highway network of a given region is inadequate to support this level of detail, reasonable professional methodologies may be developed.

Also attached for your information is a copy of a memorandum dated April 5, 1994, from David J. Brzezinski, Chief of EPA's Model Development Section in Ann Arbor, Michigan, regarding the effect of VMT growth on MOBILE5A NOx estimates. The FHWA is currently reviewing this material and intends to discuss the methodology and conclusions with EPA. The EPA conducted an analysis on the effect of VMT growth rates because of the concern that even moderate growth rates would cause mobile source NOx emissions to exceed the 1990 base-year levels. Not surprisingly, the results show that as VMT growth rates increase, the 1990 base year emission levels will be exceeded sooner. For example, for an area that has a basic I/M program and a 2 percent annual growth rate, the 1990 levels would not be exceeded until 2020. However, the same area with a 4 percent annual VMT growth rate would exceed 1990 levels by 1992 and beyond. The analysis also shows that technology will also increase the time period before the 1990 levels are exceeded. For example, an area with an enhanced I/M program and the introduction of Low Emitting Vehicles will not exceed the 1990 base-year levels by 2020 for either a 2 percent or 4 percent annual VMT growth rate. Consequently, areas that are projecting their NOx emissions to exceed 1990 base-year levels will need to more aggressively pursue transportation demand management strategies and/or "opt" into additional technological programs.

As additional information on this important subject becomes available, we will continue to provide national distribution. We would also appreciate learning of other State and local methodologies and insights for possible distribution.

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9 Attachments

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HEP-30, HEP-31, HEP-32, HEP-40, HEP-41/Files(2),
HEP-42, HEP-50

SUMMARY
Ohio NOx Analysis Methods
and
Opportunities for Further Refinement

INTRODUCTION

The Ohio DOT (ODOT) has done extensive work on their transportation modeling processes in order to comply with the air quality analysis requirements of the CAA and the recently enacted transportation conformity requirements. On March 10, 1994, Fred Ducca and John Byun of FHWA Headquarters visited ODOT to discuss issues related to conformity and NOx. Chuck Gebhardt represented ODOT. The following are findings from the visit:

1. The ODOT has done extensive work to expand the traditional 4-step transportation modeling process, both in terms of the individual link details and the time periods considered. They have also been extremely thorough in collecting field data to support these model refinements. Traffic volumes and speeds were estimated on an hourly basis. Using this model set, all the Ohio nonattainment areas evaluated showed small increases in NOx for the build compared to the no-build alternative.

2. Based on NOx speed data developed by the California Air Resources Board, ODOT developed a freeway analysis method which increases NOx emission factors associated with ramps/weaving operations, but decreases NOx emission factors associated with mainline operations (see **Attachment 2**). This method consistently reduced the difference in NOx estimates between build and no-build alternatives (see **Attachment 3**). The methodology was preliminarily discussed with EPA but until EPA can verify this methodology and modify the MOBILE5 emission factors for all States, the conformity regulations will not permit them to be used.

3. For Toledo, ODOT tested several TCMs to evaluate their ability to reduce NOx. Even though some of the strategies were aggressive (see **Attachment 4**), none were capable of reducing NOx emissions by 2 percent, even under an assumed reduction in total area auto work trips of 10 percent.

4. The FHWA review team noted that the post processor used by ODOT in estimating freeway speeds (the speed vs. volume/capacity ratio relationship) is similar to the 1985 HCM method (see **Attachment 5**). The large speed variation based on capacity is responsible for some of the increase in NOx when highway improvements are made.

   However, updates of these speed/capacity relationships are currently underway by the TRB Highway Capacity and Quality of Service Committee. New updates of the freeway curves were approved by the Committee in 1992 and were printed for the Committee on February 7, 1994. The latest research indicates that speed is almost constant with all Levels Of

Service until volume reaches the critical level (see **Attachments 6 and 7**). Also, the Committee adopted increased freeway lane capacities from 2000 passenger cars per hour per lane (PCPHPL) to 2200 PCPHPL for 4-lane freeways and 2300 PCPHPL for 6-lane freeways. Publication of the new material as a formal part of the HCM is expected later this year.

It was expected that incorporating these updates in the model would reduce the difference in NOx emissions between build and no-build analysis. Also, the entire NOx analysis would need to be re-run within the modeling framework because the assignment process would redistribute traffic among arterials and freeways based on the newly adjusted link speeds. The results of making this change in Ohio (see **Attachment 8**) raised the overall NOx estimates for both the build and the no-build cases slightly, but the build alternative became better than the no-build alternative for NOx in Springfield and Toledo, and NOx differences were reduced in the other areas.

5. The FHWA team also noted that hourly NOx emissions on freeways during off-peak periods were relatively high even though overall traffic volume on freeways was low. This effect occurred because of the large percentage of heavy-duty diesel trucks on freeways during evening off-peak periods between midnight and 4 o'clock in the morning (heavy-duty diesel vehicles emit disproportionate amounts of NOx--approximately 40-50 percent of total NOx from highway vehicles). Because speeds during these times were fairly high and NOx emission rates increase rapidly above 80 KPH (50 mph), it was expected that a speed enforcement program would significantly reduce NOx projections.

The ODOT re-ran the NOx emissions model with revised speed curves for Cincinnati and modeled a strict late night speed limit enforcement. The results are shown below:

- Total NOx for

build	alternative:	99.026 metric tons/day
no-build	alternative:	98.657 metric tons/day
	difference:	0.369 metric tons/day
percent	difference:	0.37 percent

- Impact of freeway speed enforcement 88 KPH (55 mph)

11 p.m. - 12 a.m.	-0.326 metric tons/day
12 a.m. - 1 a.m.	-0.201 metric tons/day
1 a.m. - 2 a.m.	-0.113 metric tons/day
2 a.m. - 3 a.m.	-0.180 metric tons/day
3 a.m. - 4 a.m.	-0.153 metric tons/day
4 a.m. - 5 a.m.	-0.153 metric tons/day
5 a.m. - 6 a.m.	-0.191 metric tons/day

Therefore, speed enforcement for any 3-hour period between 11 p.m. and 6 a.m. would produce NOx reductions greater than the build/no-build difference in Cincinnati.

CONCLUSIONS

1. Updating transportation models to current speed/capacity relationships will lessen the modeled NOx increase associated with the build condition, but not necessarily make it go away. Also, it may generate slightly higher mobile source NOx emission estimates for both build and no-build alternatives.

2. The Ohio NOx model analysis demonstrated that enforcing the 88 KPH (55 mph) speed limit on freeways (where the speed limit is already 88 KPH) between 11 p.m. and 1 a.m. could eliminate NOx problems for the city of Cincinnati. However, caution should be exercised before using this strategy. The program would need to be included as a mitigation strategy that is clearly linked to the build option, and would not otherwise occur. The State DOTs/MPOs would need to coordinate this TCM with EPA's regional office, State and city police departments, and FHWA's regional office to assure that such a program would be acceptable and that all parties agree on the scope and effectiveness of such a program based on public acceptability, limitations on budget, technical difficulties, or legal problems.

3. It is becoming increasingly clear that the analyses required as part of the conformity finding for transportation TIPs and Plans are showing exceedingly small differences in travel and emission estimates between build and no-build alternatives. Refinements to travel models will increase their ability to reflect small differences between options, but will not consistently eliminate the potential for modeled NOx increases for the build option over the no-build. Transportation capital investments and most TCMs may be helpful, but often produce only minor changes in mobile source emission projections, unless the proposals alter travel choices in fundamental ways and affect large segments of the traveling public, or are targeted effectively to vehicles which emit disproportionately large amounts of NOx.

Attachment 2

PROCEDURE AND ADJUSTMENTS USED BY ODOT

1. ODOT increased emissions associated with ramps and decreased emissions associated with smooth running. (Note: EPA is evaluating this technique.)

2. The ramp speeds are assumed as one half the merge or diverge speed with maximum speed being 92.8 KPH (58 mph) and minimum being 17.6 KPH (11 mph).

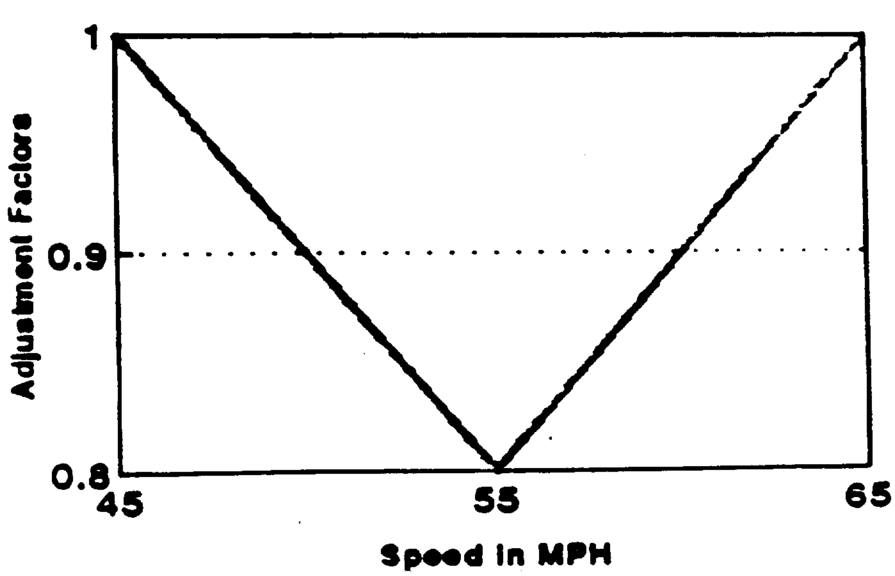
3. To better estimate the effect of acceleration or deceleration, adjustment factors are multiplied by MOBILE5A emission factors.

	Factors for Pollutant		
	HC	CO	NOx
o For Ramps:	1.5	1.5	1.0
o For Surface Arterials:	1.0	1.0	1.0

- o For freeways operating in a steady state mode with speed equal to or greater than 72 KPH (45 mph):

  - * For NOx, the factor is 0.80.
  - * For HC and CO, the factor is 1.0 at 72 KPH (45 mph) and decreases linearly from 1.0 at 72 KPH (45 mph) to 0.8 at 88 KPH (55 mph) and then increases linearly to 1.0 at 104 KPH (65 mph).

HC And CO Adjustment Factors Applied to Steady Speed Freeway



FY95 BUILD AND NO-BUILD TIP AIR QUALITY ANALYSIS FOR OHIO NONATTAINMENT AREAS

		Without Factors #		With Factors #	
Study Area	Scenario	NOx Tons/Day *	Difference in NOx	NOx Tons/Day *	Difference in NOx
AKRON	No-Build	38.375		34.280	
	Build	38.837		34.610	
		0.462	1.19%	0.330	0.95%
CINCINNATI	No-Build	92.610		84.225	
	Build	93.631		84.943	
		1.021	1.09%	0.718	0.85%
SPRINGFIELD	No-Build	8.273		7.443	
	Build	8.323		7.474	
		0.050	0.60%	0.031	0.41%
TOLEDO	No-Build	30.811		28.218	
	Build	30.975		28.366	
		0.164	0.53%	0.148	0.52%
YOUNGSTOWN	No-Build	27.315		25.105	
	Build	27.829		25.399	
		0.514	1.85%	0.294	1.16%

Source: OHIO DOT, Chuck Gebhardt

* Units are in metric tons and can be converted to English tons by multiplying by 1.1024.

\# ODOT developed factors associated with freeway ramp and mainline operations (see Attachment 2).

Toledo 1996 TCM Alternatives

1990 Network Loaded with 1996 Trips

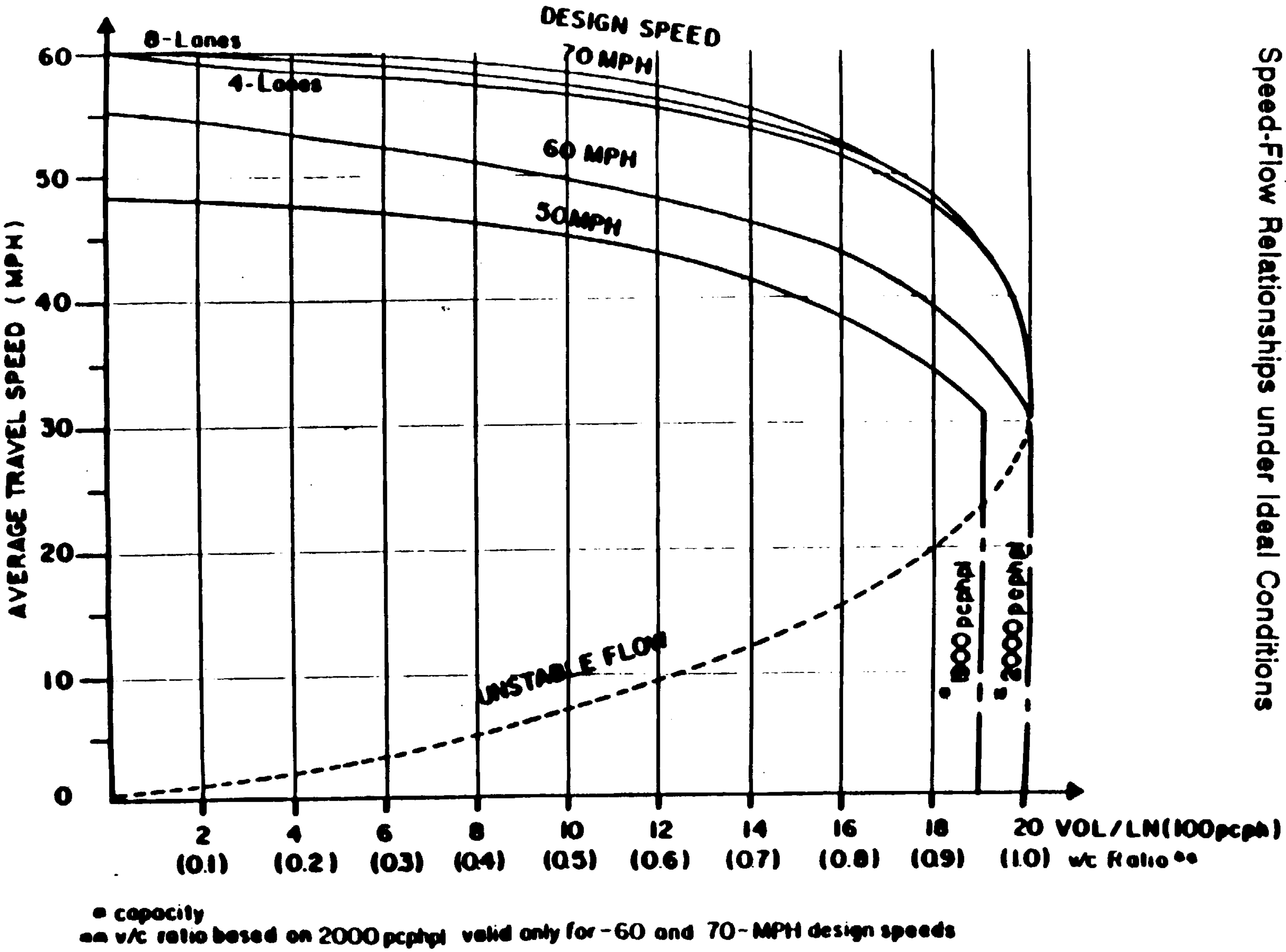
Description	Transit Trips	NOx Tons/Day *	Difference in NOx #
1996 No-Build Base Case Base Transit Fare = $.50	22,966	20.285	
Transit Fare = $.25	37,244	20.231	-0.26%
Transit Fare = $.00	61,232	20.133	-0.75%
Add Parking Cost $5.00 (where fee imposed)	65,170	20.093	-0.94%
Auto Out of Pocket Cost (10% Increase)	25,436	20.148	-0.68%
Auto Out of Pocket Cost (25% Increase)	28,104	20.074	-1.04%
Transit Frequency (50% Increase)	33,042	20.236	-0.24%
Transit Frequency (100% Increase)	38,952	20.212	-0.36%
Auto Work Trip (5% Reduction)	22,966	20.203	-0.40%
Auto Work Trip (10% Reduction)	22,966	19.916	-1.82%

Source: OHIO DOT, Chuck Gebhardt

* Total daily mobile source NOx in metric tons. MOBILE4.1 was used for the study.

Individual TCMs were evaluated and compared with 1996 no-build base case.

1985 Highway Capacity Manual:
Speed-Flow Relationships under Ideal Conditions

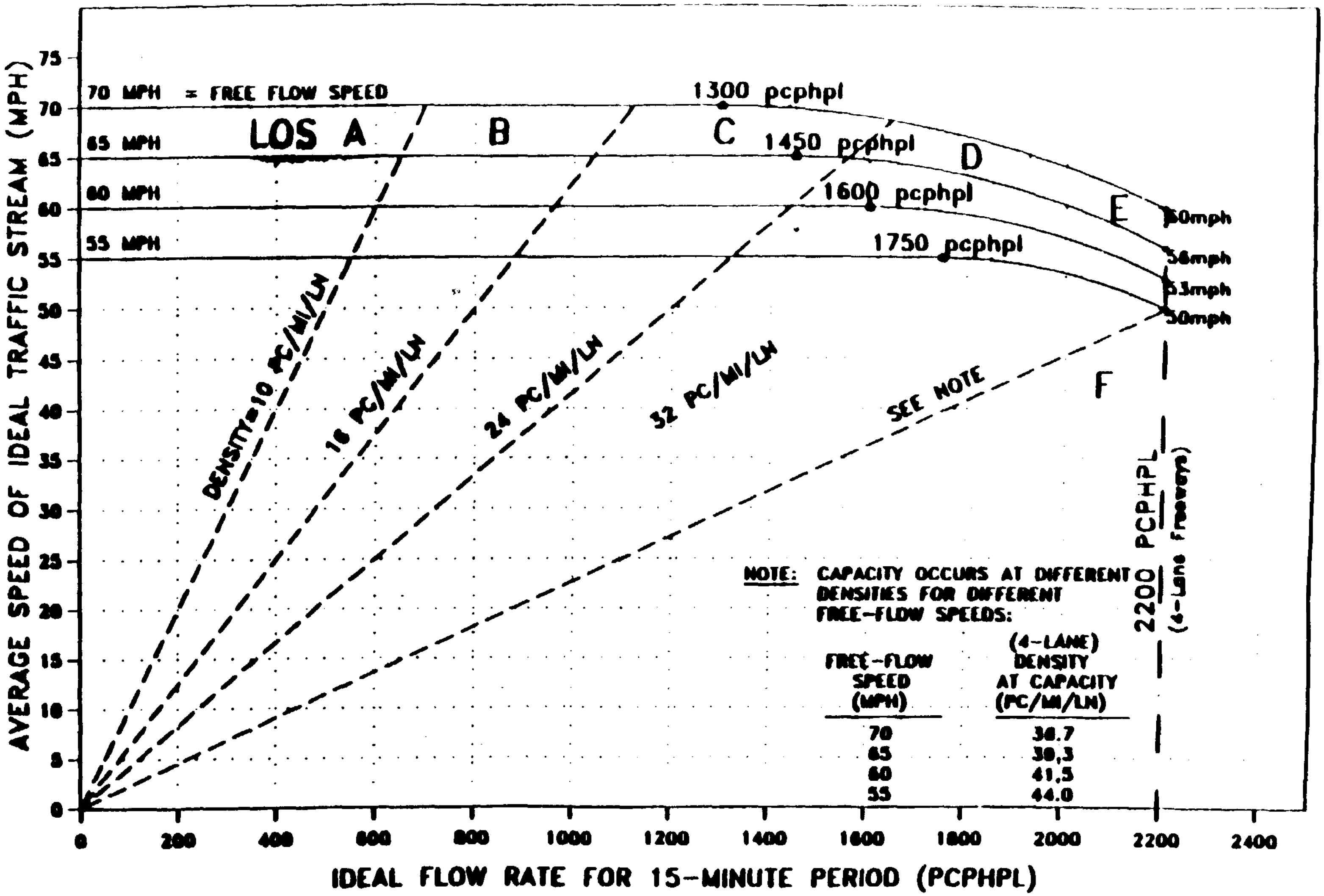


Source: Highway Capacity Manual, Special Report 209
Transportation Research Board, 1985.

Attachment 5

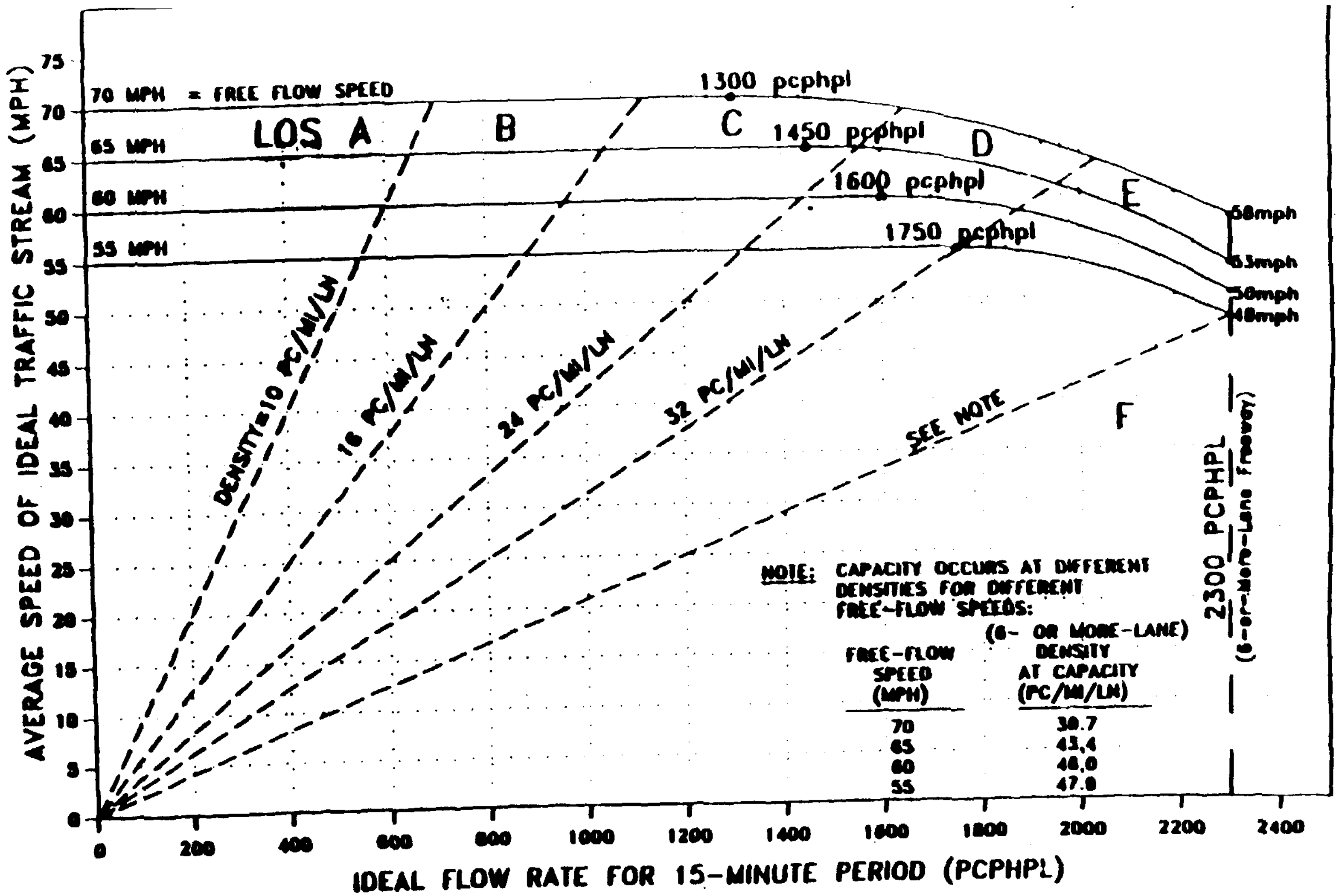
Attachment 6

Forthcoming 1994 Highway Capacity Manual:
Speed-Flow Relationships for Four-Lane Freeways



Source: Chapter 3, Basic Freeway Sections
Highway Capacity and Quality of Service Committee
Transportation Research Board
Additional Revision February 7, 1994

Forthcoming 1994 Highway Capacity Manual:
Speed-Flow Relationship for 6- or More-Lane Freeways



Source: Chapter 3, Basic Freeway Sections
Highway Capacity and Quality of Service Committee
Transportation Research Board
Additional Revision February 7, 1

Attachment 7

FY95 BUILD AND NO-BUILD TIP AIR QUALITY ANALYSIS FOR OHIO NONATTAINMENT AREAS WITH NEW SPEED CURVE

Study Area	Scenario	NOx Tons/Day *	Difference in NOx
AKRON	No-Build	40.641	
	Build	40.837	
		0.196	0.48%
CINCINNATI	No-Build	98.657	
	Build	99.026	
		0.369	0.37%
SPRINGFIELD	No-Build	8.525	
	Build	8.516	
		-0.009	-0.10%
TOLEDO	No-Build	32.691	
	Build	32.667	
		-0.024	-0.07%
YOUNGSTOWN	No-Build	28.046	
	Build	28.445	
		0.399	1.40%

Source: OHIO DOT, Chuck Gebhardt

* Units are in metric tons and can be converted to English tons by multiplying by 1.1024.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
ANN ARBOR MICHIGAN 48105

OFFICE OF
AIR AND RADIATION

April 5, 1994

MEMORANDUM

SUBJECT: Effect of VMT Growth on MOBILE5 NOx Estimates

FROM: David J. Brzezinski, Chief
Model Development Section, AQAB

TO: Philip A. Lorang, Director
Emission Planning and Strategies Division, OMS

THRU: Lois A. Platte, Chief
Air Quality Analysis Branch, EPSD

There is some concern that future highway mobile source fleet emissions of oxides of nitrogen (NOx) will exceed base year 1990 levels even with moderate growth in vehicle miles travelled (VMT). We have examined this issue and provide the following analysis.

Using the latest version of the MOBILE5 model (March 26, 1993), a base scenario was chosen using the following parameters:

- o Summer temperatures (72 to 92 degrees fahrenheit)
- o National average fleet characteristics
- o Industry average fuel characteristics at 8.7 psi RVP
- o National average hot/cold start VMT fractions

Other parameters were varied to investigate their effect on the trend in emissions. Primary in these was the assumed I/M program description, since I/M can affect current and future NOx emission levels. The following I/M program descriptions were used:

Basic Program

- o 1983 program start year
- o 40% stringency factor
- o 1968 and newer model year vehicle coverage
- o No waivers
- o 100% compliance rate
- o All gasoline vehicle classes covered
- o Test-only, biennial inspections
- o Idle test procedure (all model years)
- o Full anti-tampering program (all components)

IM240 Program

o Same as Basic Program except:
o IM240 test procedure for all model years
o Cutpoints: 0.8/20/2.0 g/mi HC/CO/NOx

All scenarios were done at 19.6 miles per hour. Non-I/M cases were done at 27 and 50 miles per hour to investigate the potential effect of speed on the NOx results. Also, one case was done assuming introduction of new vehicles certified to the new Low Emitting Vehicle (LEV) standards proposed by California. The model was evaluated every other calendar year from 1990 through 2020. Growth rates from zero to 6% were assumed and applied linearly to the 1990 base NOx levels. The results of the analysis are presented in the attached tables.

Table 1 shows the non-I/M case at 19.6 miles per hour. In this case a growth rate of 2% will cause NOx emission levels to exceed 1990 base NOx emission levels, but not until calendar year 2020. A 3% growth will cause NOx emission levels to exceed the 1990 base NOx emission levels immediately. Fleet turnover, however, keeps NOx levels close to the 1990 levels until 2010, when the growth in VMT overcomes fleet turnover and emission increase continuously.

Table 2 shows the Basic I/M case at 19.6 miles per hour. The Basic I/M program design reduces NOx emissions by deterrence of tampering behaviour and repairs of tampering with emission control devices that control NOx emissions. In this case, as in the non-I/M case, a growth rate of 2% will cause NOx emission levels to exceed 1990 base NOx emission levels, but not until calendar year 2020. A 3% growth will not cause NOx emission levels to exceed the 1990 base NOx emission levels until calendar year 2000. A 4% growth causes NOx emissions to increase continuously. In this case, if it is assumed that in the 1990 base year there was no I/M program, the 1990 NOx emission target would be 3.000 g/mi. Therefore, if the I/M program were applied after the base year as a control strategy, at a 3% growth, the I/M program would delay the exceedance of the 1990 base levels until calendar year 2010.

Table 3 shows the IM240 I/M case at 19.6 miles per hour. The IM240 I/M program design identifies high NOx emitting vehicles using an IM240 test and requires their repair in addition to identifying vehicles with tampering. In this case, a growth rate of 2% will not cause NOx emission levels to exceed 1990 base NOx emission levels until sometime after calendar year 2020 (the limit of the model). A 3% growth will not cause NOx emission levels to exceed the 1990 base NOx emission levels until calendar year 2020. A 4% growth causes NOx emissions to exceed 1990 levels in calendar year 2012. A 5% growth causes NOx emissions increase continuously. As before for the Basic I/M case, if it is assumed that in the 1990 base year there was no I/M program, the 1990 NOx emission target would be 3.000 g/mi. Therefore, if the I/M program were applied after the base year as a control strategy, at a 3% growth, the I/M program would not exceed the 1990 base levels until after calendar year 2020. The exceedance for a 4% growth would be delayed until calendar year 2014. Even a 5% growth would not cause an exceedance until calendar year 2008.

Table 4 repeats the IM240 I/M case at 19.6 miles per hour assuming introduction of new vehicles certified to the new Low Emitting Vehicle (LEV) standards proposed by California. These vehicles will be subject to a more stringent IM240 exhaust emissions cutpoints resulting in emission rates which will, on average, meet the emission standards for these vehicles at 50,000 miles. The LEV program is phased in starting in 1994 and is fully operational by 2003. In addition to the NOx reducing effects of the I/M program, the lower new vehicle NOx standards continues the effect of fleet vehicle turnover. In this case, a growth rate of 5% will cause NOx emission levels to exceed 1990 base NOx emission levels until 2000 when the reduction in emissions due to the LEV program outweighs the VMT growth. The LEV program continues to cause reductions until sometime after calendar year 2020 (the limit of the model). Similarly, a 6% growth will cause NOx emission levels to exceed the 1990 base NOx emission levels until calendar year 2000. But, the LEV program causes a reduction for the period 2000 through 2012. As before for the Basic I/M case, if it is assumed that in the 1990 base year there was no I/M program, the 1990 NOx emission target would be 3.000 g/mi. Therefore, if the I/M program were applied after the base year as a control strategy, up to a 6% growth, the I/M program would not exceed the 1990 base levels until after calendar year 2020.

Most urban areas have fleet average trip speeds greater than 19.6 miles per hour. For comparison, the non-I/M case was repeated assuming an average trip speed of 27 miles per hour and are shown in Table 5. In this case, although the absolute NOx emission rates have changed, the effect of growth on exceedance of the 1990 base NOx emission levels is similar. A similar table done with a speed of 50 miles per hour shows a similar outcome. This demonstrates that the effect of speed on absolute NOx emission levels is not a major factor in the exceedance of 1990 base NOx emission levels.

Table 6 shows the factors used to increase the emission rates to reflect increases in VMT as a result of growth. Growth was assumed to be a linear increase in VMT from the base year level.

cc: T. Newell
C. Radwan
J. Armstrong, ECSB

Table 1

All Vehicle Fleet NOx Emission Rate (g/mi) with Growth
Without I/M Case (19.6 mph)

Calendar		Growth Rate						
Year	Year	0%	1%	2%	3%	4%	5%	6%
1990	0	3.000	3.000	3.000	3.000	3.000	3.000	3.000
1991	1							
1992	2	2.830	2.887	2.943	3.000	3.056	3.113	3.170
1993	3							
1994	4	2.689	2.797	2.904	3.012	3.119	3.227	3.334
1995	5							
1996	6	2.536	2.688	2.840	2.992	3.145	3.297	3.449
1997	7							
1998	8	2.419	2.613	2.806	3.000	3.193	3.387	3.580
1999	9							
2000	10	2.274	2.501	2.729	2.956	3.184	3.411	3.638
2001	11							
2002	12	2.153	2.411	2.670	2.928	3.186	3.445	3.703
2003	13							
2004	14	2.061	2.350	2.638	2.927	3.215	3.504	3.792
2005	15							
2006	16	2.015	2.337	2.660	2.982	3.305	3.627	3.949
2007	17							
2008	18	1.973	2.328	2.683	3.038	3.394	3.749	4.104
2009	19							
2010	20	1.950	2.340	2.730	3.120	3.510	3.900	4.290
2011	21							
2012	22	1.931	2.356	2.781	3.205	3.630	4.055	4.480
2013	23							
2014	24	1.920	2.381	2.842	3.302	3.763	4.224	4.685
2015	25							
2016	26	1.916	2.414	2.912	3.410	3.909	4.407	4.905
2017	27							
2018	28	1.916	2.452	2.989	3.525	4.062	4.598	5.135
2019	29							
2020	30	1.917	2.492	3.067	3.642	4.217	4.793	5.368

Table 2

All Vehicle Fleet NOx Emission Rate (g/mi) with Growth
Basic I/M & ATP Case (19.6 mph)

Calendar Year	Year	Growth Rate 0%	1%	2%	3%	4%	5%	6%
1990	0	2.947	2.947	2.947	2.947	2.947	2.947	2.947
1991	1							
1992	2	2.764	2.819	2.875	2.930	2.985	3.040	3.096
1993	3							
1994	4	2.614	2.719	2.823	2.928	3.032	3.137	3.241
1995	5							
1996	6	2.470	2.618	2.766	2.915	3.063	3.211	3.359
1997	7							
1998	8	2.357	2.546	2.734	2.923	3.111	3.300	3.488
1999	9							
2000	10	2.215	2.437	2.658	2.880	3.101	3.323	3.544
2001	11							
2002	12	2.097	2.349	2.600	2.852	3.104	3.355	3.607
2003	13							
2004	14	2.007	2.288	2.569	2.850	3.131	3.412	3.693
2005	15							
2006	16	1.962	2.276	2.590	2.904	3.218	3.532	3.846
2007	17							
2008	18	1.921	2.267	2.613	2.958	3.304	3.650	3.996
2009	19							
2010	20	1.898	2.278	2.657	3.037	3.416	3.796	4.176
2011	21							
2012	22	1.879	2.292	2.706	3.119	3.533	3.946	4.359
2013	23							
2014	24	1.868	2.316	2.765	3.213	3.661	4.110	4.558
2015	25							
2016	26	1.864	2.349	2.833	3.318	3.803	4.287	4.772
2017	27							
2018	28	1.864	2.386	2.908	3.430	3.952	4.474	4.996
2019	29							
2020	30	1.865	2.425	2.984	3.544	4.103	4.663	5.222

Table 3

All Vehicle Fleet NOx Emission Rate (g/mi) with Growth
IM240 & ATP I/M Case (19.6 mph)

Calendar Year	Year	0%	1%	2%	3%	4%	5%	6%
		Growth Rate						
1990	0	2.854	2.854	2.854	2.854	2.854	2.854	2.854
1991	1							
1992	2	2.615	2.667	2.720	2.772	2.824	2.877	2.929
1993	3							
1994	4	2.408	2.504	2.601	2.697	2.793	2.890	2.986
1995	5							
1996	6	2.213	2.346	2.479	2.611	2.744	2.877	3.010
1997	7							
1998	8	2.062	2.227	2.392	2.557	2.722	2.887	3.052
1999	9							
2000	10	1.906	2.097	2.287	2.478	2.668	2.859	3.050
2001	11							
2002	12	1.784	1.998	2.212	2.426	2.640	2.854	3.068
2003	13							
2004	14	1.691	1.928	2.164	2.401	2.638	2.875	3.111
2005	15							
2006	16	1.643	1.906	2.169	2.432	2.695	2.957	3.220
2007	17							
2008	18	1.599	1.887	2.175	2.462	2.750	3.038	3.326
2009	19							
2010	20	1.576	1.891	2.206	2.522	2.837	3.152	3.467
2011	21							
2012	22	1.561	1.904	2.248	2.591	2.935	3.278	3.622
2013	23							
2014	24	1.552	1.924	2.297	2.669	3.042	3.414	3.787
2015	25							
2016	26	1.549	1.952	2.354	2.757	3.160	3.563	3.965
2017	27							
2018	28	1.550	1.984	2.418	2.852	3.286	3.720	4.154
2019	29							
2020	30	1.551	2.016	2.482	2.947	3.412	3.878	4.343

Table 4

All Vehicle Fleet NOx Emission Rate (g/mi) with Growth
LEV Stds. with Full IM240 & ATP I/M Case (19.6 mph)

Calendar Year	Year	Growth Rate 0%	1%	2%	3%	4%	5%	6%
1990	0	2.854	2.854	2.854	2.854	2.854	2.854	2.854
1991	1							
1992	2	2.615	2.667	2.720	2.772	2.824	2.877	2.929
1993	3							
1994	4	2.403	2.499	2.595	2.691	2.787	2.884	2.980
1995	5							
1996	6	2.183	2.314	2.445	2.576	2.707	2.838	2.969
1997	7							
1998	8	2.028	2.190	2.352	2.515	2.677	2.839	3.001
1999	9							
2000	10	1.847	2.032	2.216	2.401	2.586	2.771	2.955
2001	11							
2002	12	1.670	1.870	2.071	2.271	2.472	2.672	2.872
2003	13							
2004	14	1.496	1.705	1.915	2.124	2.334	2.543	2.753
2005	15							
2006	16	1.364	1.582	1.800	2.019	2.237	2.455	2.673
2007	17							
2008	18	1.252	1.477	1.703	1.928	2.153	2.379	2.604
2009	19							
2010	20	1.163	1.396	1.628	1.861	2.093	2.326	2.559
2011	21							
2012	22	1.094	1.335	1.575	1.816	2.057	2.297	2.538
2013	23							
2014	24	1.056	1.309	1.563	1.816	2.070	2.323	2.577
2015	25							
2016	26	1.036	1.305	1.575	1.844	2.113	2.383	2.652
2017	27							
2018	28	1.025	1.312	1.599	1.886	2.173	2.460	2.747
2019	29							
2020	30	1.021	1.327	1.634	1.940	2.246	2.553	2.859

Table 5

All Vehicle Fleet NOx Emission Rate (g/mi) with Growth
Without I/M Case (27 mph)

Calendar Year	Year	Growth Rate 0%	1%	2%	3%	4%	5%	6%
1990	0	2.968	2.968	2.968	2.968	2.968	2.968	2.968
1991	1							
1992	2	2.801	2.857	2.913	2.969	3.025	3.081	3.137
1993	3							
1994	4	2.670	2.777	2.884	2.990	3.097	3.204	3.311
1995	5							
1996	6	2.522	2.673	2.825	2.976	3.127	3.279	3.430
1997	7							
1998	8	2.401	2.593	2.785	2.977	3.169	3.361	3.553
1999	9							
2000	10	2.255	2.481	2.706	2.932	3.157	3.383	3.608
2001	11							
2002	12	2.133	2.389	2.645	2.901	3.157	3.413	3.669
2003	13							
2004	14	2.043	2.329	2.615	2.901	3.187	3.473	3.759
2005	15							
2006	16	1.997	2.317	2.636	2.956	3.275	3.595	3.914
2007	17							
2008	18	1.955	2.307	2.659	3.011	3.363	3.715	4.066
2009	19							
2010	20	1.933	2.320	2.706	3.093	3.479	3.866	4.253
2011	21							
2012	22	1.913	2.334	2.755	3.176	3.596	4.017	4.438
2013	23							
2014	24	1.902	2.358	2.815	3.271	3.728	4.184	4.641
2015	25							
2016	26	1.897	2.390	2.883	3.377	3.870	4.363	4.856
2017	27							
2018	28	1.897	2.428	2.959	3.490	4.022	4.553	5.084
2019	29							
2020	30	1.897	2.466	3.035	3.604	4.173	4.743	5.312

Table 6

All Vehicle Fleet NOx Emission Rate (g/mi) with Growth
Without I/M Case (50 mph)

Calendar Year	Year	Growth Rate 0%	1%	2%	3%	4%	5%	6%
1990	0	3.499	3.499	3.499	3.499	3.499	3.499	3.499
1991	1							
1992	2	3.264	3.329	3.395	3.460	3.525	3.590	3.656
1993	3							
1994	4	3.088	3.212	3.335	3.459	3.582	3.706	3.829
1995	5							
1996	6	2.900	3.074	3.248	3.422	3.596	3.770	3.944
1997	7							
1998	8	2.741	2.960	3.180	3.399	3.618	3.837	4.057
1999	9							
2000	10	2.560	2.816	3.072	3.328	3.584	3.840	4.096
2001	11							
2002	12	2.410	2.699	2.988	3.278	3.567	3.856	4.145
2003	13							
2004	14	2.299	2.621	2.943	3.265	3.586	3.908	4.230
2005	15							
2006	16	2.244	2.603	2.962	3.321	3.680	4.039	4.398
2007	17							
2008	18	2.195	2.590	2.985	3.380	3.775	4.171	4.566
2009	19							
2010	20	2.168	2.602	3.035	3.469	3.902	4.336	4.770
2011	21							
2012	22	2.143	2.614	3.086	3.557	4.029	4.500	4.972
2013	23							
2014	24	2.130	2.641	3.152	3.664	4.175	4.686	5.197
2015	25							
2016	26	2.125	2.678	3.230	3.783	4.335	4.888	5.440
2017	27							
2018	28	2.125	2.720	3.315	3.910	4.505	5.100	5.695
2019	29							
2020	30	2.125	2.763	3.400	4.038	4.675	5.313	5.950

Table 7

NOx Emission Rate
Assumed Linear Growth Factors

Calendar Year	Year	Growth Rate 0%	1%	2%	3%	4%	5%	6%
1990	0	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1991	1							
1992	2	1.000	1.020	1.040	1.060	1.080	1.100	1.120
1993	3							
1994	4	1.000	1.040	1.080	1.120	1.160	1.200	1.240
1995	5							
1996	6	1.000	1.060	1.120	1.180	1.240	1.300	1.360
1997	7							
1998	8	1.000	1.080	1.160	1.240	1.320	1.400	1.480
1999	9							
2000	10	1.000	1.100	1.200	1.300	1.400	1.500	1.600
2001	11							
2002	12	1.000	1.120	1.240	1.360	1.480	1.600	1.720
2003	13							
2004	14	1.000	1.140	1.280	1.420	1.560	1.700	1.840
2005	15							
2006	16	1.000	1.160	1.320	1.480	1.640	1.800	1.960
2007	17							
2008	18	1.000	1.180	1.360	1.540	1.720	1.900	2.080
2009	19							
2010	20	1.000	1.200	1.400	1.600	1.800	2.000	2.200
2011	21							
2012	22	1.000	1.220	1.440	1.660	1.880	2.100	2.320
2013	23							
2014	24	1.000	1.240	1.480	1.720	1.960	2.200	2.440
2015	25							
2016	26	1.000	1.260	1.520	1.780	2.040	2.300	2.560
2017	27							
2018	28	1.000	1.280	1.560	1.840	2.120	2.400	2.680
2019	29							
2020	30	1.000	1.300	1.600	1.900	2.200	2.500	2.800